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PRECIPITATION

-COMMUNIST CHINA-

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CHINA'S EXPERIMENTS IN ARTIFICIAL PRECIPITATION

[This is a translation of an article written by CH'ENG Shun-shu of the Central Observatory, Central Meteorological Bureau, in Ch'i-hsiang Hsueh-pao (Journal of Meteorology), Peiping, Vol XXX, No 3, pages 286-290.]

China's research work on experiments in artificial precipitation began only a little more than nine months ago. Since the nation's work is of such short standing, any attempt to evaluate its scientific significance at this time would be premature. The sole purpose of this article is to present, together with certain observations, an over-all report on the results obtained and the data accumulated in the course of the experiments.

In 1958 all the people of China successfully liberated their thoughts and vigorously developed a revolutionary spirit, under the brilliant guidance of the Party's general line of socialist construction and on the basis of the victory of the rectification movement.

As a result, a high tide of the big leap forward occurred on various production fronts, with agriculture by far leading the way. This new situation created many, and varied, new problems and tasks for the meteorological workers of China.

Scientific and technical work, under the leadership of the Party, should be primarily geared to the development of production and for service to socialist construction; and science should be motivated by "missions." In accordance with this correct policy, the schedule of experimental and research work on controlling certain aspects of weather by artificial means, set forth in the research plan for meteorological science, was accelerated. The decision was also reached that field experiments in artificial pre-

precipitation should be undertaken as the first step in furthering this branch of science on the basis of production needs.

In an effort to solve the problems posed by the arid climate of Northwest China and to satisfy the requirements of the big leap forward in agricultural and industrial production of that area, the Academia Sinica joined hands with the Meteorological Bureau and Peiping University and performed a series of experiments in artificial precipitation in the Ch'i-nien Shan area of Kansu Province.

The purpose of these experiments was to determine the possibility and practicality of artificial precipitation in Northwest China, so that the experience so acquired would facilitate preparation for the next stage of work. The first stage of work¹ was carried out during the period of August-October 1958.

On another front, a severe drought--the most severe one for scores of years--occurred in the city of Kirin and its environs during the period of July-August 1958, when the crops needed water most. The entire population of the area was mobilized in an anti-drought movement. Large-scale experiments in artificial precipitation were carried out under the leadership of the² City Committee, and the results were very satisfactory.

Cloud-seeding was performed 19 times with large quantities of dry ice. Instead of seeding the clouds individually as in a scientific experiment, a large amount of dry ice was scattered over a vast area of cumulus, cumulonimbus and alto-stratus or nimbo-stratus clouds. Several hundred kilograms of dry ice were used in each seeding, the maximum amount being one-and-one-half tons.

The maximum flight path was 300 kilometers. The airplane flew in and out of the cumulus and cumulonimbus clouds generally at an altitude between 6,000 and 7,000 meters. The results of these experiments not only helped solve the problems of local drought but also greatly enlightened the vast number of meteorological workers in China.

Before the winter of 1958, a number of experiments in artificial precipitation and cloud and fog dispersion were

carried out in the areas of Nanking, Wuhan and Hopeh Province,^{3,4} and more experience was thus acquired. Artificial cloud-making in the clear⁵ skies over Nanking was also tried with notable results.

In early December 1958, a conference was held in Peiping to exchange experiences in artificial precipitation [experiments] carried out in various localities in the summer and autumn, and to discuss ways and means of expanding the experiments in 1959. The conference recognized that artificial precipitation--important and promising as it was--was still in an experimental stage, and that it was still under the control of natural, material and technical conditions--especially when carried out by means of an airplane.

The conference further maintained that experiments in artificial precipitation could be further developed only in key areas, that experience therein could be summarized, that scientific research work could be vigorously expanded, and that conditions could be prepared in a positive way.

The conference also pointed out that even though little work on artificial precipitation had been done hitherto in ground-level laboratories, and that even though experience in this respect was very limited in China, the most practicable way to solve the problems was still through laboratories on the ground. To this end, the mass of the people should be mobilized by various methods, and both native and foreign techniques should gradually be incorporated and applied.

On the basis of the requirements and the weather conditions in the various areas, the conference finally selected several key areas and decided upon the principal lines of research and experimentation for the following year.

The experimental work on artificial precipitation has already attracted enormous attention throughout China. After a period of technical exchange and propagation, the [number of] location [sites] and the number and [diversity of] method of experimentation in artificial precipitation increased considerably since the winter of 1958. Table 1 shows the condition and the number of experiments which took place in various localities from August, 1958 to March, 1959.

Table 1. Showing Cloud Structures, Results, and Number of Experiments in Artificial Precipitation Performed from August 1958 to March 1959. (Substances used in experiments also shown)

	As		Ac		Ns		Sc		Cb		Cu		St,	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Aerial Experiment	6		3	1	6	1	17	8	52	5	1			
Ground Experiment	10	3	5	5	1		8	7	3	2	3	2	1	
Salt, Salt Water			1		1		4	4	12					
Powdered Lead*	1	2	1	2			1				1		1	
Gamphor*								3			1	2		
Cus	2		1					1						
Water											1			
Dry Ice	4		3	1	6		13	4	32	4	1			
Silver Iodide	9	1	4	1	1		7	3	3	2	1			
Lime											1			

Notes: (1) Yes = Effective; No = Ineffective or Effect unknown

(2) Some experiments in April also included

* Other substances might be added.

The statistics shown in Table 1 can hardly be considered complete because of incomplete returns. Besides, the method and scale of the experiment and the degree of accuracy in analyzing observation also varied greatly in the various areas.

In view of these facts, Table 1 at best indicates a general picture of the experiments. Regarding the methods of appraising results in the experiments, no detailed reports were available, because of the restriction of time and the many experimental conditions.

The table was compiled on the basis of conclusions or preliminary suggestions of the original reports. The general criterion used in appraising the results is as follows: the experiment is called "effective," whenever it produces rain, drizzle, or "yu-fan," or whenever the clouds show a definite reaction.

To determine whether the experiment is effective, or not effective, is a difficult procedure. Besides, the difference in conditions under which the experiments were conducted in various localities should also be considered. The scanty data in Table 1 can hardly be used as a basis for a detailed comparison, nor should it be considered as a conclusive scientific record.

It should be noted that in the columns under "Yes" in Table 1, less than one-half of the strato-cumulus, cumulo-nimbus and cumulus congestus clouds which had been seeded yielded rain and that the other cloud forms hardly yielded any rain at all.

Most of the experiments which dealt with clouds with vertical development such as the cumulo-nimbus, cumulus congestus, and cumulus humilis clouds in Table 1 were carried out in summer. Reports on these experiments have been published and need no repetition here.

In winter most of the clouds assume the stratus form. The seeding of these clouds was often effective, but the effect in most cases was not noticeable. The winter stratus cloud, particularly in north China, is generally three to five hundred meters thick.

Even near the frontal area it is only one thousand meters thick. It contains very little moisture, and the cooling effect of the dry ice is limited to a small area. Thus the conditions for enlargement of water droplets are much less favorable in the stratus than in the cumulus cloud.

Furthermore, since the stratus drifts horizontally at a high speed, seeding must be repeated many times consecutively before any appreciable effect can be produced.

The winter weather in China is characteristic in that it is usually fair and dry, is under the influence of high pressure centers or cold airs, and is otherwise of a systematic nature. Such weather is often capable of producing precipitation.

Recently, experimental conditions do not permit us much choice in selecting weather conditions. Hence, a considerably large proportion of the more effective experiments were performed within the scope of systematic precipitation.

Under the circumstances it is most difficult to evaluate objectively the effectiveness of the experiments. In addition, the present status of the observation network and analytic research make it hard to draw accurate conclusions.

The data derived from experiments which have been considered relatively effective by the participants thereof are listed in Table 2. The "+" sign in the last column of the table denotes the amount of increase in addition to natural precipitation, on the basis of preliminary estimates.

In this article, it does not seem advisable to have a full discussion on the ways and means whereby the effectiveness of the experiments was determined.

Table 2 also indicates the results of those experiments in which substances other than dry ice and silver iodide were used. However, these experiments are very few in number, and they will not be discussed in this article.

From Table 3, it may be observed that experiments with warm clouds were carried out 23 times within the prescribed period. However, no conclusions have been drawn from these experiments, in view of the fact that the methods of determining the effectiveness of the experiments and the procedure of the experiments (such as the strength of the salt, etc.) varied greatly among the localities.

Table 2

Experimental Site	Date	Type of Cloud	Substance Used	Effectiveness Estimated in Terms of Rainfall (mm)
Kirin City	21 Mar	Ns	Dry Ice	+3
	22	Ns	Dry Ice	+2
	23	Ns	Dry Ice	+2
Tung-kang	3 Dec	As tra	AgI	+0.5
	9	Ns Fs	AgI	+2
Tientsin	30 Dec	As	Dry Ice with Salt	+1
T'ung-liao, Inner Mongolia	21 Mar	Ns	Dry Ice	+4
Hangchow	6 Apr	As Sc	AgI	+5
Shanghai	1 Jan	As Fs	AgI	+2
	7	Ns	AgI	+4
Sining, Tsing-hai	18 Mar	As Fs	AgI, Powdered Lead, Camphor	+3
Lu Shan	21 Dec	Ac dup	Powdered Lead, Camphor, Amethyst	+2
Ho-fei	31 Dec	Sc op	AgI	+1

The figures enclosed in brackets are estimates by the writer on the basis of the original report.

Table 3

Cloud Type Substance Used	Sc				Ac				As	
	Salt		Dry		AgI		Camphor		Dry	
	Water		Ice						Ice	
	O	X	O	X	O	X	O	X	O	X
Warm Cloud	3	3	2	1		1	*		1	1
Warm Cloud about 0°C	2	2	3		2			1		

<u>Fc</u>					
Powdered Lead				Total	
O		X		O	X
				7	5
1				8	3
				} 23 times	

Notes: O = Effective; X = Ineffective

Δ = Ice and salt were used in one experiment

* Natural precipitation was in progress, when the experiments were carried out

Warm cloud about 0°C signifies a cloud with a temperature at its top of not higher than 2°C.

Table 4

Cloud Type Substance Used	Sc						Fog		Cu	Ns
	Dry Ice	Salt	Lime				Camphor	Salt Smoke	Dry Ice	Salt
	0	X	0	X	0	X	X	X	0	0
Cold Cloud		2					1*		1	
Warm Cloud	3 Δ	1	8	1	1	1	1	1		1

Notes: O = Effective; X = Ineffective

Δ = Ice and salt were used in one experiment

* AgI solution was added.

During this period, experiments in the dispersion of cloud and fog were carried out 22 times, as indicated in Table 4. (Experiments not designed to disperse clouds are not included in this table, but in the tables dealing with artificial precipitation.) The effect of salt on warm clouds is affirmative.

Two experiments, one with ice and salt water and the other with dry ice, were performed at Ku-ch'eng, Hopeh Province, on 24 August. The temperature at the top of the cloud was as high as 10°C and the effect of the experiment was pronounced. The stratus cloud was partially dispersed for as long as 15 to 20 minutes; this is a noteworthy feat.

Dry ice was used in an experiment at Tientsin on 14 September, but the result was undetermined. "Yun-kou" [literally, cloud trenches] still existed. Powdered salt was once used to seed warm cloud without success (26 December, Nanking). This experiment should not be counted,

because only three kilograms of powdered salt were used, an amount too insignificant to have an effect.

The seeding of cold clouds with powdered salt was successful in two cases: one for strato-cumulus clouds (at T'angshan, 9 March) with temperatures of 0°C at their bases and -5°C at their tops--relatively warm as cold clouds go-- and the other at Ts'ang Hsien for strato-cumulus clouds, which had a base at 2,100 meters and a peak at 2,400 meters. During the day, in the latter case, the temperature at 750-800 mb over Peiping was between 0° and -2.8°C ; therefore, the clouds were comparatively warm.

In both cases, the seeding involved only a limited area of cloud and had a rather high rate. Either several dozen kilograms to one hundred kilograms of dry ice, or approximately one hundred to 270 kilograms of powdered salt, or 520 kilograms of salt water were dropped in each experiment. The reports on these experiments did not clearly indicate the size of the trenches and openings [in the clouds].

However, in one experiment at Ningpo on 14 April, 97 kilograms of powdered salt were dropped into the strato-cumulus clouds, which immediately broke up and exposed, within ten minutes, the blue skies over an area of about 30 square kilometers. During this period [from August 1958 to March 1959], no experiments in cloud dispersion were conducted on a scale larger than those described above.

Since the success of the experiment in cloud-making at Nanking⁵ in November (1958), these experiments were conducted seven times in Nanking, Ts'ang Hsien and Kirin. Cloud strips were formed in four of the seven experiments, and in two experiments the strips lasted eight to minutes. At the time, the estimated relative humidity of the air layer was between 70 and 80 percent and the temperature between 17 and 20°C below freezing point.

As a whole, it is very difficult to form clouds in air layers with high temperatures and low relative humidities; on the other hand, clouds may be readily made artificially in air layers with very low temperatures and high relative humidities. However, clouds so induced will not last long.

In the winter of 1958-1959, in addition to performing the above experiments, the various scientific organs and key experimental areas in China were busily engaged in organizational work and technical preparations. They designed and manufactured the cloud-seeding apparatus used in conjunction with an airplane, so that the dropping of cloud-seeding substances in large quantities into the clouds may be more effectively carried out. A considerable number of rainfall observation points were organized for the sole purpose of ascertaining the results of the experiments. A small cloud laboratory was designed to test new cloud-inducing substances.

These science organs and key experimental areas also designed the basic instruments used on the ground and in an airplane for the study of the dynamics of clouds and fog. A part of the research and observation work has also been started.

Many localities have been engaged in this line of research. Small rockets have been used to shoot inoculants, such as silver iodide crystals, into the clouds. The primary concern at the moment is how to increase the altitude to be reached by the inoculants. The use of anti-aircraft gun to shoot silver iodide crystals into the clouds has already undergone preliminary tests.

Finally, the problems of hail will be discussed briefly in this article. Hail is one of the most serious natural hazards in many relatively high and cold areas of China. In these areas the growing season is short and the occurrence of hail during the period of growth of crops is very likely to cause great damage. In recent years, some areas have vigorously embarked on a struggle against hailstorms.

For instance, in Hao-ch'ing⁶, Yunnan, many very large work teams and more than one hundred fixed hail-prevention points have been established; cannon and smoke have been used to bombard the clouds in an effort to prevent the formation of hail. The people were deeply impressed with the work, and damage caused by hail is decreasing as the years go by. Their success is based on accurate observations of the development of the cumuliiform types of cloud and their excellent experience in forecasting. This

year will see meteorological work teams taking part in hail prevention work in many localities, in an effort to tackle the problems by application and through learning from the masses.

The work of the last nine months has brought us most encouraging results, but it only represents the initial stage of our research. In 1959 experimentation on induced precipitation will be expanded in the key areas. to vigorously establish conditions for a speedy development of the work on artificial precipitation during the next few years, this writer is of the opinion that the following four problems should be taken into consideration, in addition to strengthening organizational work and increasing the supplies of materials and equipment:

1. The experiments should be devised more accurately and with greater intricacy. The purpose of the experimentation is to test the complex scientific and technical problems involved in the control over aspects of the weather by artificial means, to reveal gradually the various conditions under which the physical processes of clouds evolve, and to acquire accurate and reliable records and data.

With the experience thus accumulated and summarized, the technical skill may be raised to a point where its practical application in production is possible.

Each experiment should have definite purpose and a practical procedure. The weather for experimentation should be carefully chosen. More consideration should be paid to the analysis of local weather processes and to detailed observation and investigation of changes in weather phenomena in the area. Failure in this would not only make the summarization of experience impossible but also would hinder the progress of the entire project.

2. The over-all physical observation and study of clouds should be developed. The over-all conditions and the various stages of development of clouds should be understood before the technique in cloud-seeding can be improved. Study along this line should be well planned and further developed, so that cloud-seeding may be conducted on a larger scale.

3. The major tasks for this year should be determined. A system of division of labor should be instituted concerning work done in the air and work done at ground level. Steps should be studied and taken to effectively develop the work to be done on the ground, so that the national expenditure may be reduced.

4. The mass line should be strictly carried out, and the policy of using both "domestic" and "foreign" methods should be enforced. With hail prevention work as a starting point, we should mingle with the masses, and learn and practice their experience and innovations.

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